

experienced. Kerosene lanterns froze up at -55° F. (-48° C.) and dry-cell flashlights were rendered useless also. Self-generating dynamo flashlights furnished the only source of light for outside use during the severe cold weather.

In conclusion it may be well to emphasize the fact that there is still an enormous field for meteorological research in Antarctica. Professor Hobbs has long pointed out the great value which would accrue from a year's observations on the polar plateau; such work would be possible although attended with extreme difficulties and

hardships to the personnel involved. Simultaneous records at a number of points over the continent are also needed before a really comprehensive and intelligent study may be made of the laws which govern atmospheric action in the southern latitudes. Each expedition has added a bit more to this knowledge yet the field of operations of one or two isolated parties has necessarily been limited. The extent and rapidity of future research hinges, as heretofore, upon the generosity of the people and of organizations in offering financial support for expeditions.

REPORT OF THE STREAM-FLOW PREDICTION SUBCOMMITTEE¹

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The past year was characterized by a greatly increased universal interest in the possibilities of estimating stream flow, which previously has been and, in many professional and scientific quarters, still is regarded as being wholly a fortuitous sequence. During the past decade this viewpoint had gradually undergone a radical change, until to-day many earnest investigators recognize the presence of definite systematic elements in stream flow which permit conclusions to be drawn as to future run-off well in advance of occurrence.

PAST METHODS OF PREDICTION

In the planning of hydraulic projects, the manner of estimating future discharge quantities in the past has rested on a rather questionable basis, untenable on scientific grounds, and dictated by necessity rather than secure, basic knowledge. If stream flow is to be regarded as wholly fortuitous sequence, then the theory of probability is directly applicable to the estimate of future performance. Much has been theorized on future probability (probability a priori) based on past performance or experience (probability a posteriori) or so-called empirical determination of probability. It is a well-established fact that only a voluminous series of data can furnish a secure basis for future expectation. Such data must, moreover, be wholly freed from systematic sequences.

Instead of thousands of observations, hydraulic engineers usually have at their disposal only a few records covering not more than 10 to 50 years. It is evident that 50 dice throws will not give the same average as several thousand, and if systematic changes are introduced, such as changing the throw, the dice, etc., no reliable estimate of future averages based on previous performance is possible. Yet, this is the meager basis on which all hydraulic projects hitherto have been based. The future is held to have the same average, as well as limits of variation, as the past records indicate.

NEW METHODS OF PREDICTION

Certain it is, that stream flow records never repeat themselves, and ceaseless fluctuations exist, continually moving to higher and lower levels apparently in often recognizable systematic sequences. In Europe these have

been studied and applied by Dr. Axel Wallen (Twelve Years of Long Distance Prognostication of Rainfall and Waterlevels, *Annals der Hydr. und Maritim. Meteorology*, September 1926, pp. 89-92), director of the hydrographic service in Sweden. Here, too, much research has been applied to finding a better way of estimating future stream flow. It is the near future which is of the greatest importance in hydraulic power projects, and this may be radically different from the immediate past; enough to create the difference between earned or not earned interest on outstanding bonds.

UTILITY OF PREDICTIONS

Experience of the past 10 years indicates that public utilities which derive their power supply in whole or in part from hydroelectric plants can apply these studies profitably to the appraisal of their future power supply. It appears that for the Great Lakes division it is quite possible to estimate hydraulic power output a year in advance to within 5 per cent. The general trend can be forecast for several years to follow, and thereby the steam power and coal supply requirements can be budgeted more accurately. No errors need be made as by one utility, which constructed an expensive booster pump installation for their circulating water just in advance of the rise in levels of the Great Lakes, or by another in the Great Lakes region, which hurriedly installed expensive additional boiler capacity to take care of threatening shortage just in advance of a rising hydraulic power output.

STREAM FLOW IN GREAT LAKES REGION

The Great Lakes region appears to be distinguished by a singularly regular multiannual sequence of stream flow, which enables close estimates of water power. Naturally such estimates are of greater value, the greater the amount of available storage. Without storage the annual (seasonal) variation determines the requirements of steam power; peak capacity is not affected by a variation of the annual mean, although even in such cases the annual coal supply is still subject to calculation in advance. Members of the Great Lakes division are enabled to utilize the knowledge of these systematic sequences of stream flow in the Great Lakes region to the extent above indicated.

The discovery of this regular cycle in stream flow is due to the hydrologist, Robert E. Horton (United States

¹ Extracted from the 1929-30 Report Hydraulic Power Committee, Engineering Section, National Electric Light Association, Great Lakes division. Presented at the tenth annual convention, French Lick, Ind., Sept. 25-27, 1930.

Geological Survey Water Supply Paper No. 30). Since 1875 the cycle has faithfully recurred 10 times. At present a minimum is approached which will occur in 1931. A further maximum will occur in 1935, and a high maximum in 1940. The hydroelectric companies in the Great Lakes region will profitably note that next year will be a poor water year, and their hydro output will compare with the previous low around 1925.

On the other hand, abundant hydro output will be available in the Great Lakes region around 1934-1936.

STREAM FLOW IN MICHIGAN

For Michigan the graph shown in Figure 1 is illuminating. This graph represents the flow of the Muskegon River in Michigan. It may be seen that the relation with

It should be mentioned that the lower peninsula of Michigan has, on account of its heavy cover of glacial drift, a very great volume of ground storage, which favors the exact realization of these estimates. Next year a minimum output of hydro in Michigan will occur, the deficiency being as high as 37.5 per cent of the 1928 hydro output.

In a personal letter to the editor, Mr. Streiff comments on the methods of stream-flow prediction as follows:

JACKSON, MICH., January 25, 1931.

DEAR PROFESSOR HENRY: Hydraulic engineers thus far have been in a quandary. In a continental climate, as that of the United States, the water problem is, for great parts of the country, that of a deficiency. The economics of projects costing millions depend on an accurate estimate of the quantity of water which is available, or will be, in the future. The theory that future averages will be equal to past averages has led to financial failures in a number of

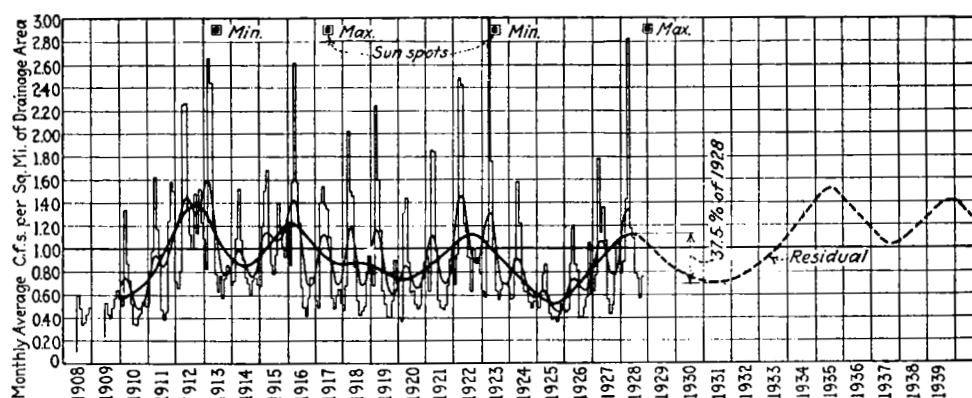


FIGURE 1.—Stream-flow prediction for Muskegon River, Mich.

the maxima and minima of the Wolf numbers is striking. This graph was prepared in 1928 and first published in the periodical Power of April, 1929. The dotted line shown thereon is the probable extension of the annual mean stream flow as it appeared to the chairman of this subcommittee in the year 1928. The dotted line drops sharply, indicating dry years in 1930 and 1931. The present drought fully supports the estimate made two years ago. The estimates of power output for the Consumers Power Co. have checked as follows: For 1928, error 5 per cent; for 1929, error 2 per cent; for 1930 the first half of the year exactly corresponded with the estimate.

cases. I have personally been involved in two of them during the past 20 years.

Hence we have been forced to cast about for other solutions, and while we believe we are on the right path, this is strictly an engineering belief. Engineers are in every branch striding far ahead of scientific certainties and proceed on "opinion," "judgment," "hunch," and so forth. Hydrodynamics is still in a very elementary stage as far as the possibility of computing flow of water is concerned, but still engineers build water turbines of 93 per cent efficiency, largely empirically.

Hence the report should be regarded from that standpoint. It is a technical expedient. I fully disclaim its scientific value. And it should be regarded as wholly in the field of hydraulic engineering. I really feel very little informed about meteorology.

Respectfully yours,

A. STREIFF.